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Mapping of landscape structure and forest cover change detection in the mountain chains around Addis Ababa: The case of Wechecha Mountain, Ethiopia

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ABSTRACT

Addis Ababa, the capital city of Ethiopia is, a tropical city, found on a high elevation between 2000 m and 3000 m above sea level. The city is bordered by high rise mountains, Entoto Mountain in the North, Wechecha Mountain in the West, Furi Mountain in the South and Yerer Mountain in the East which have a crucial influence on determining the climate of the city. This study, therefore, focuses on landscape structure and forest cover change on Mount Wechecha, which has a great contribution in the regulation of modifying micro climate of the city and the environ, not only due to its elevation but also due to its dense forest cover. Monitoring land cover changes in a mountain ecosystem help to understand and pinpoint the strategy to be followed for the conservation of ecosystems found on the neighbouring mountains, which also have a great influence on regulating the climate of the city. The study uses five Landsat satellite images to derive land cover of Mount Wechecha from 1973 to 2013. Landscape structures and matrixes have been analyzed and mapped based on the patch-corridor-matrix ecological model. The results have shown that the patch analyst result is proportional to the land cover classes derived from the satellite image. The landscape structure indices of the number of patches are decreasing in all years, except for water and settlement. The forest patches are dissolved into agricultural lands. The mean core area of the forest that increases indicates that the forest coverage is limited to certain places. The Mean Core Area of agricultural land decreased in the last decade due to the agricultural land being interrupted by other economic activities, which leads to landscape modifications. Shannon's evenness and diversity index was zero. The overall result indicates that the forest, which play a great role in climate regulation and open land coverages are decreasing at a faster rate (30% and 24.5% in 1973–14% and 2.4%. in 2013 respectively), while settlement is highly increasing (from 1.3% to 26.25% same period). Hence, the priority has to be given to protecting forest loss of Mount Wechecha and other forests on the neighbouring mountains surrounding Addis Ababa in order to have favorable climate conditions in the city. Such type of studies on mountain chains are very vital in considering appropriate environmental planning mechanisms and to formulate policies at the landscape level.

1. Introduction

Landscape structure is understood as a group of elements determining the landscapes and their spatial relationships. Landscape structure is the pattern of a landscape, which is determined by its type of use, and by its structure, i.e. the size, shape, arrangement and distribution of individual landscape elements (Walz, 2011), which vary, depending on the approach to the landscape essence. The two main landscape structure formulas in landscape ecology researches are geographical landscape and ecological landscape (Cieszewska, 2000). In geographical landscape, landscape elements are land units called geocomplexes based mainly on abiotic components and in the ecological landscape, the landscape analysis is based on the patch - corridor - matrix model - with domination of biotic features. According to Li and Reynolds (1995), the landscape structure is determined by five components. These are number of cover types, proportion of each type, spatial arrangement of patches, patch shape and contrast between patches that theoretically describe landscape structure. A landscape is a kilometers-wide area where a cluster of interacting stands or ecosystems are repeated in similar form (Forman and Godron, 1981). Landscape structure is a result of the complex interactions between physical, biological, political, economic and social driving forces. Most

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landscapes have been influenced by human land use, and the resulting landscape mosaic is a mixture of natural and human-managed patches that vary in size, shape, and arrangement (Turner et al., 1989). Landscapes have different species, energy and materials distribution and therefore differ functionally in the flows of species, energy and materials among the elements (Forman and Godron, 1981). Landscape structure could also be described by its composition and configuration. Landscape composition refers to features associated with the presence and amount of each patch type within the landscape, but without being spatially explicit (McGarigal and Marks, 1995; Menon and Sasidharan, 2005). Typical measures of landscape composition include the proportion of the landscape in each patch type, patch richness, patch evenness, and patch diversity (McGarigal and Marks (1995) On the other hand, landscape configuration (sometimes referred to as landscape pattern) refers to the physical distribution or spatial character of patches within the landscape and it is a mixture of natural and human-managed patches that vary in size, shape and arrangement (McGarigal and Marks, 1995; Forman and Godron, 1986; Turner, 1990). In spite of the conceptual differences between these two components, in practice they are often closely related in space and time. Landscape structure is maintained or changed under a balance of the effectiveness between natural and anthropogenic disturbances (Menon and Sasidharan, 2005).

Technological advances, in spatial data handling softwares and availability of remotely sensed spatial data from satellite images as well as the development of geographic information systems (GIS) for storing, manipulating, and displaying spatial data, provided the tools for studying spatial patterns over broad spatial scales (Turner et al., 2001). Since the introduction of satellite remote sensing, various researches have been undertaken using satellite images for land use land cover analyses and change detection studies. Land cover refers to the actual surface cover for a given location. Remote-sensing data has a long history of being used for deriving land-cover maps, even before the launch of the first Landsat platform in 1972. Remote sensing also has the ability to map and monitor changes in surface conditions, which are not related to a direct change in land cover or land use, most notably that of vegetation condition (Vogelmann et al., 2009).

Land cover changes specifically forest changes and deterioration over the past century is reported from various parts of Ethiopia (Reusing, 2007; Dar al, 2011). This in turn made the landscape structure to be modified and lose its origin. Environmental factors like deforestation, overharvesting of crops above the carrying capacity of the land and permanent conversion to other forms of land use is leading to shrinkage of forest resources. As a result, forest cover has been declining rapidly and only remnant forests are confined to some areas especially in the South and South-Western parts of the country, which are less populated (Bekele, 2002). Researches indicated that Ethiopian forest cover has continuously declined from the original 35% forest cover in 1950–2.4% in 1992 (Sayer et al., 1992). The change detection analysis, based on satellite images of 1973–1976, indicate that in the seventies, natural high forests covered around 4.75% of the country. Around 10–15 years later, only around 0.20% of the country was still covered by undisturbed natural forests (Reusing, 2000). In recent years also, specifically in highest mountains, which were previously covered by dense forests, the deforestation was continued at an alarming rate in different parts of the country (Getahun et al., 2013; Dessie and Kleman, 2007; Hailemariam et al., 2016) mainly in mountainous areas (Zeleke and Hurni, 2001; Molla et al., 2010).

The same is true for the forest remnant areas found in the mountains in central Ethiopia and surrounding Addis Ababa. Due to high rapid informal settlement and urban expansion, the urban land is getting expanded to this natural mountain forests and the planned green areas are now resettled. Addis Ababa is the capital and largest city of Ethiopia, with a total projected population of 3.44 million people in 2017. Addis Ababa is home to 25% of the urban population in Ethiopia and is one of the fastest growing cities in Africa. It is the growth engine for Ethiopia and a major pillar in the country's vision to become a middle-income, carbon-neutral, and resilient economy by 2025. The city alone currently contributes approximately 50% towards the national GDP; highlighting its strategic role within the overall economic development of the country (World Bank, 2015). The city is bounded by four known mountains in four directions. These are Mount Entoto from the North, Mount Erer from the East, Mount Furi from the South and Mount Wechecha from the West. These mountains are covered by forests and play a pivotal role in climate regulation of Addis Ababa city.

As the city is surrounded by high mountains, the topography is undulating and form plateau in the northern, western and southwestern parts of the city. Bole and south western part of the city is characterized by gentle morphology and flat land areas. As a result, the stream drains towards south from the Entoto ridge; southeast direction from Mt. Wechecha and Mt. Furi and towards southwest direction from Mt. Erer and other elevated areas of the eastern outskirts of the city. The main objective of this paper is therefore to analyze and map the landscape structures based on the patch-corridor-matrix ecological model and to detect forest cover changes on Wechecha Mountain with their temporal dynamics and evaluate the trends for the past 40 years. Analysis of the long-time landscape change of the Wechecha Mountain indicates the prevailing condition of mountainous landscapes of Ethiopia currently and suggest strategies to be followed to alleviate the current environmental problems like climate change in largest cities.

2. Methodology

2.1. Study area

2.1.1. Geographical location

Wechecha Mountain is found in central highlands of Ethiopia, South West of Addis Ababa in Sebeta Hawas and Wolmera woredas of Oromia Special Zone Surrounding Finfinne in Oromia regional state between 8°54′N-9°4′N latitude and 38°29′E- 38°40′E longitude. The total area of the study site covers 22,521 ha. Towns like Menagesha Kolobo and some parts of Sebeta are also found on this landscape. Gefersa reservoir which is managed by Addis Ababa Water and Sewage Authority is also found in the northern foot of the mountain, 18 km west of Addis Ababa. The Gefersa River and its feeder streams are part of the Akaki river catchment. The study area is delineated based on the small watersheds and elevation characteristics derived from the DEM with 30 m spatial resolution. The mountain area is digitized considering the shape of the small watersheds on the mountain using ArcGIS.

Mountains are different from other types of land surfaces due to their significant elevation. Slope, aspect, complexity and heterogeneity of climatic, vegetation, faunal and land use distribution patterns are all outcome of this primary factor, relief (Ghosh et al., 2000; Kapos et al., 2000) divides the world's Mountain into seven classes based on the criteria of altitude and slope in combination to represent the world's mountain environments. These classes were

Class 1(elevation ≥ 4500 m), Class 2, (3500–4500 m),Class 3, (2500–3500 m),Class 4, (1500–2500 m and slope ≥ 2),Class 5, (1000–1500 m and slope ≥ 5 or local elevation range (7 km radius) _300 m), Class 6, (300–1000 m and local elevation range (7 km radius) _300 m outside 23_N—19_S), Class 7, (isolated inner basins and plateaus less than 25 square kilometers in extent that are surrounded by mountains but do not themselves meet criteria 1–6 (this seventh class was introduced in the 2002 revision of the original 2000 system)). The study area of the map is given in Fig. 1.

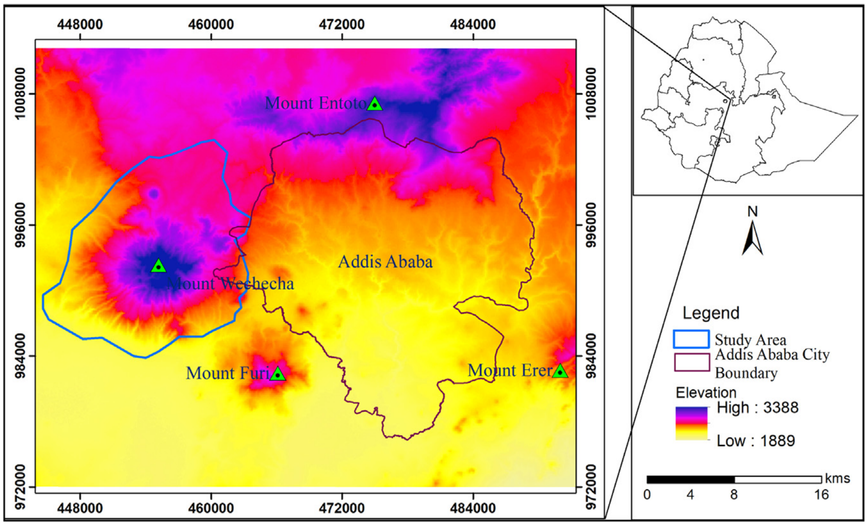

Fig. 1. Map of the study area.

2.1.2. Topography

According to Kapos classification, Mount Wechecha falls under Class 3(2500–3500 m) and Class 4(1500–2500 m and slope ≥ 2°). The elevation of the mountain ranges from 2113 m to 3388 m above sea level. Most parts of the mountain have an elevation greater than 2500 m above sea level. The mountain is characterized by rugged topography and steep slope. The Mountain is also characterized by high human and livestock population, dega agro ecological zone, water catchments for the Awash River, and source of water for the Gefersa dam and has significant biodiversity. Unfortunately, Mount Wechecha can also be considered as one of the most degraded mountain ridges surrounding Addis Ababa (PHE, 2010). Mount Wechecha is a reflection of the Ethiopian highland degradation in many ways because of land deforestation, land degradation and settlement expansion in a hilly areas. Triangulated Irregular Network(TIN) Model, a vector-based representation of the physical land surface of Mount Wechecha with three-dimensional coordinates that are arranged in a network of non over lapping triangles is given in Fig. 2 as follows.

2.1.3. Vegetation and wild life

The study area is known because of the two protected forests, Menagesha Suba and Egdu Forest. Menagesha Suba state forest is located about 45 km southwest of Addis Ababa. It covers 3418 ha. Egdu forest is one of the remnant dry afromontane forests in central Ethiopia and the forest has an altitudinal gradient ranging from 2580 to 2910 m above sea level. It covers total area of 486 ha and it is home for a wealth of flora and fauna. It is characterized by dissected island plateau surrounded by cultivated land in all direction. *Regarding the vegetation species as studied by Adugna* et al., *2013 Juniperus procera, Olea europaea* subsp. *cuspidata, Olinia rochetiana, Maytenus arbutifolia, Rhamnus staddo, Rhus vulgaris, Eucalyptus globulus, Acacia abyssinica* and *Myrica salicifolia, Pittosporum viridiflorum, Maytenus obscura* and *Osyris quadripartita* are the species dominating the forest and *Acacia mearnsii, Erica arborea* and *Cupressus lusitanica* are the dominant species at the higher altitudes. There are planted species as a result of plantation activities at the peak and in most of open areas bordering the forest. *Pinus patula, Cupressus lusitanica, Acacia mearnsii* and *Eucalyptus globulus* are the planted species found on Mount Wechecha. On the other hand Menagesha Suba State Forest is one of the oldest conserved forests in Africa(Sahle, 2011).

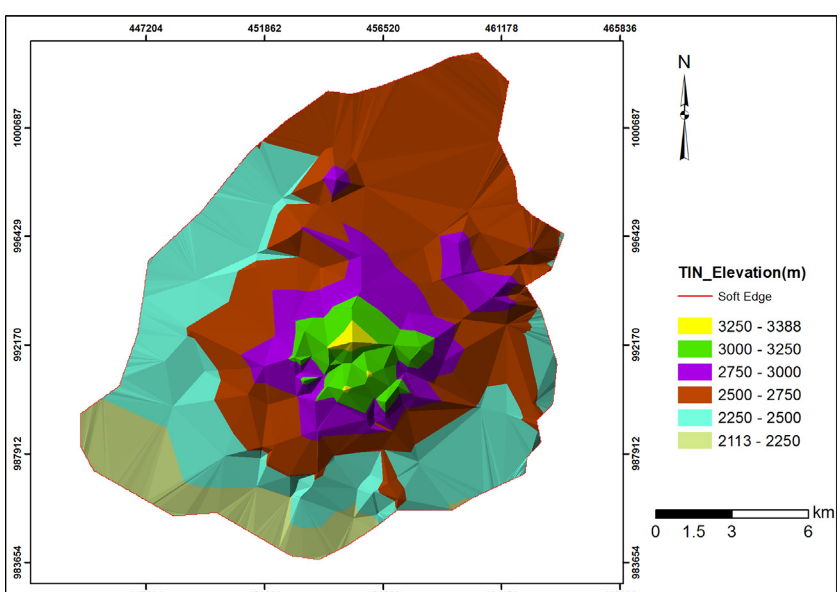

Fig. 2. TIN Model of the study area.

Fig. 3. Photos of the study area: Mount Wechecha (left), and Egdu Forest(right).

The two forest sites found on the mountain is the habitat of numerous wild animals, including baboons, colobus monkeys, bushbucks, bush pigs, ghenet, caracal, spotted hyena, wildcat and a variety of bird species (Senbeta and Teketay, 2001) Except for these two protected sites, the major vegetation type planted in most parts of the study area is eucalyptus tree. (Fig. 3).

2.1.4. Climate

The temperature information is derived from Holeta Meteorological station which is the nearest station with temperature record. Accordingly the mean temperature of the study area is 14.32 °C and maximum average temperature is 22.22 °C and Minimum average temperature is 6.45 °C for the periods between 1977 and 1997. High temperature record was from March to May. The maximum temperature in May reaches 23.8 °C. November and December are the coldest months with minimum average temperature falls below 3 °C.The average maximum temperature, mean and minimum temperature is given in Fig. 4.

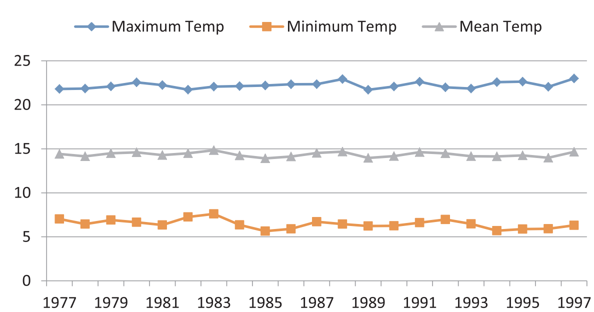

Fig. 4. Temperature trend in the study Area (1977–1997).
Source: NMSA, Data compiled by the author.

The precipitation information is derived from Sebeta meteorological station found near the study area at an elevation of 2569 m above sea level. The average precipitation of the study area was 1106 mm from 1983 to 2012. July, August and September are rainy months. The highest precipitation record was in August. The rainfall record reaches up to 222 mm in this month. December and January are dry months. The average monthly precipitation distribution is given in Fig. 5 below.

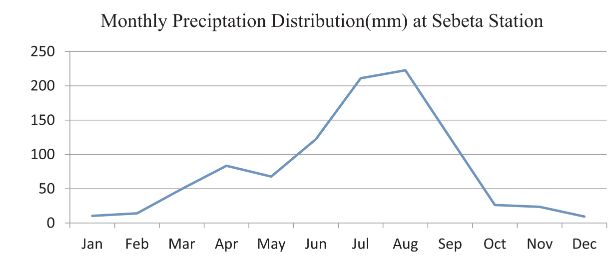

Fig. 5. Rainfall distribution.
Source: NMSA, Data compiled by the author.

2.2. Data source

The data source for the study area is mainly based on the satellite images. Remote sensing approach has been used as an effective tool for detecting the landscape change and for long-term monitoring. Land use land cover (LULC) classification and mapping for various-period images were used to detect the LULC type change (Van Lynden and Mantel, 2001). For this study, first, the satellite images were downloaded from USGS site using path 168 and 169 paths and row 54. The digital elevation model data was also used to classify the topography of the study area. Table 1 shows the characteristics of Landsat image satellite images used for the analyses in the study area. The 60 m resolution of MSS data was resampled to 30 m in order to have similar spatial resolution using nearest neighborhood assignment resampling algorithm on arc GIS. The characteristics of Landsat image used for the analyses is summarized in Table 1.

Table 1
Characteristics of landsat satellite images used for the analyses.

No.	Data Type	Sensor	Path	Row	Resolution(m)
1	Landsat 1973	MSS	181	54	60
2	Landsat 1984	TM	169	54	30
3	Landsat 1993	ETM	168	54	30
4	Landsat 2003	ETM	168	54	30
5	Landsat 2013	Landsat 8	168	54	30

In Addition to the analyses of satellite data field observation in some parts of Mount Wechecha and information's about the history of the area is gathered through unstructured interviews with some locality farmers of the study area. Photographs by the researcher and other sources, additional information from the review of secondary data and

Google Earth information have also been incorporated.

2.3. Data analyses techniques

The technical data analyses included three Parts. These were land cover classification, NDVI calculation and Landscape Metrics generation.

A. **Landover Cover Classification**
The satellite image of 1973, 1984, 1993, 2003 and 2013 has been processed using ERIDAS Imagine. The coordinate system, image mosaicking, layer stacking and layer extraction took place before classification. The classification method is supervised classification, with maximum likelihood algorithm. During the classification process, the points collected by the handheld GPS in the field were considered. In the endfive land cover types have been identified and classified.

B. **Landscape Structure Metrics derivation**

Once the land cover types are identified, the analyses of landscape structures followed. The landscape structure has been analyzed using the landscape indices. The landscape indices are generated using patch analyst version 2.2 extension tool in ArcGIS which is also an extension for Fragstats software. The generated landscape indices has been divided into three groups (McGarigal et al., 2002):

- **Patch-level metrics**, which are measures of individual patches and their spatial character or context,
- **Class-level metrics**, which are measures of one patch type (class) existing in the landscape and can either be derived by averaging or calculated separately, so that they reflect an aggregate property of the patches in a particular cover type,
- **Landscape-level metrics** are measures extending over the whole of a landscape and are similarly derived by averaging or calculated using all the patches in all classes.

With regard to landscape analyses the following analyses were undertaken using patch analyst extension

- **Landscape patch analysis**: Landscape patch, as the base of landscape pattern, can be described by the number of landscape patterns, the quantity of each pattern, the area of each pattern, the average area of patch, the coefficient of area variation for patch, standard difference of area, max patch index and so on. These characters can reflect the status of landscape pattern.

- **Patch shape index analysis**: The shape index of patch is generally the proportion of the width of a patch to the area of the patch.
- **Fragmentation analysis**: Fragmentation of landscape is the process that the landscape changes from simple to complex due to the natural and artificial factors. There are many indices to describe fragmentation. In this paper, average area, fractal dimension, departure and density of patches were used to analyze the fragmentation of the landscape in study area. Generally speaking, for a patch, the larger the degree of human activity, the simpler the geometry shape of the patch, leading to more linear boundary, the lower the fractal dimension of the patch and vise versa.
- **Landscape pattern analysis**: The Shannon's diversity and evenness index were used to analyze landscape pattern.

The main advantage of patch – corridor - matrix model is a functional aspect - it is mostly focused on relations between elements. On the other hand, map of geocomplexes give the spatial dispersion of most components not only land cover. Both are applied in planning from local to regional (Cieszewska, 2000).

2.3.1. Metrics definitions

The landscape and class level metrics are derived from the land use land cover maps identified previously using ArcGIS and patch analyst software. All the maps are converted to GRID format to be analyzed in patch analyst extension software. Even though, it is possible to derive various indices, using the software only few metrics are selected for the landscape structure analyses. Although there were a number of metrics developed to describe and quantify elements of patch shape complexity and spatial configuration relative to other patch types; the provided definitions for the metrics were derived from McGarigal and Marks (1995). A short description of metrics definition used in the analyses is presented in Table 2.

Table 2
Landscape Metrics selected for this study (the definitions are adopted from McGarigal and Marks, 1995).

Acronym	Metric	Description
CA	Class Area	Sum of areas of all patches belonging to a given class
TLA	Total Landscape Area	Sum of areas of all patches in the landscape
TCA	Total Core Area	The total size of disjunct core patches.
MCA	Mean Core Area	The average size of disjunct core patches.
TCAI	Total Core Area Index	Measure of amount of core area in the landscape
CAD	Core Area Density	The relative number of disjunct core patches relative to the landscape area.
SDI	Shannon's Diversity Index	Measure of relative patch diversity. The index will equal zero when there is only one patch in the landscape and increases as the number of patch types or proportional distribution of patch types increases
SEI	Shannon's Diversity Index	Measure of patch distribution and abundance. Shannon's evenness index is equal to zero when the observed patch distribution is low and approaches one when the distribution of patch types becomes more even
MSI	Mean Shape Index	Shape Complexity. MSI is equal to 1 when all patches are circular (for polygons) or square (for rasters (grids)) and it increases with increasing patch shape irregularity
MPFD	Mean Patch Fractal Dimension	Shape Complexity. MPFD approaches one for shapes with simple perimeters and approaches two when shapes are more complex.
MPS	Mean Patch Size	Average patch size.
AWMPFD	Area Weighted Mean Patch Fractal Dimension	Shape Complexity adjusted for shape size
TE	Total Edge	Perimeter of patches.
ED	Edge Density	Amount of edge relative to the landscape area.
NumP	Number of Patches	Total number of patches in the landscape(class)

3. Results

3.1. Land cover dynamics of the study area

The land cover type of the Mount Wechecha is broadly classified into five dominant land cover classes. These are Water body, settlement (built up area), forest, agriculture and open land. These classification outputs are later used in indices generation for the analyses of the landscape structure of the mountain. The shape, size, dimension, fragmentation, class characteristics of patches are all derived from these classified land cover classes. On this classification non-built-up land with no or insignificant vegetation cover, pasture lands, and bare grounds are classified together as open land. These classifications took United States Geological Survey (USGS) land use classification system as a base which was developed by Anderson et al. (1976). These are a broad division of the land cover types of the study area.

The first land use analyses for this classification has been started with the oldest 1973 Multispectral Scanner (MSS) Data. At this time, the coverage of the forest area was high. Due to insignificant built up area, the pressure on available forest is not widely identified. The settlements are rarely identified from the resampled 30 m image. Even though agriculture was a dominant land cover type at this time, the forest cover also shared the highest coverage. Only 329 ha of land are identified as settlement or built up area during this time. Open land has also the highest share during this time found at the peak of the mountain, areas with little vegetation cover, and some parts of the foot of the mountain. Forests account 7559 ha and open lands covered 6161 ha. In 1984, however, significant shrink is observed for open lands. The open lands decreased to 2892 ha from 6161 ha in 1984 compared to 1973. The agricultural land is raised to 16,369 ha from 10982 ha. Other land covers didn't show a significant change. The land cover classes of 1973 and 1984 are presented in Fig. 6 below.

In between 1993 and 2003 the agricultural land coverage is stagnant with nearly similar area coverage between two periods. However open land is still reduced to only 1036 ha in 2003. Gefersa Reservoir increased in size during this time. Settlement coverage also abruptly increased to 3058 ha in 2003. Forest cover still continued to decrease within these two periods. This time forests are found only at protected forest sites. The land cover type of the 1993 and 2003 is given in Fig. 7.

The last and recent land cover classification for this study was of 2013. Unlike the previous maps, the land cover map this time was produced from Landsat 8. Based on the information inferred, agricultural land decreased to 14,111 ha after its share reached peak in between 1993 and 2003. Settlement coverage grows to 6580 ha during this time. All land cover classes decreased in size except for water and settlement. Gefersa Reservoir continuous to increase and reaches 123 ha in 2013. As discussed in the previous classification, this time also forests remained in protected sites. For this image,the settlement included some parts of town Sebeta and Mengesha, the settlements established following main roads as well as some factories and flower farms. This makes the area of settlement higher. Generally settlements increased from 1.3% to 26.25%, waterbody increased from 0.33% in 1973–2013 while forest decreased from 30% to 14.5%, and open land decreased from 24.5% to 2.4%. Agricultural land didn't indicate a significant change (increased from 43% to 56% but with a decreasing trend in current decade). The land cover class of 2013 is indicated in Fig. 8

It is believed that the settlement coverage became high due to fast urbanization and the expansion of factories and flower farms. The rate at which the settlement increased in the recent decade is different from the previous ones. The natural forests and man-made forests are confined only to the protected areas, unless the man-madeeucalyptus trees are found around the Gefersa Reservoir and in some Kebeles. Starting from the top of the mountain to the foot of the mountain, different traditional agricultural practices take place.

Due to the mountain being devoid of trees, the soils are exposed to erosion; as the mountain area has high rainfall intensity mainly during summer time. Only some open spaces that are not favorable for agriculture are found at the top of the Mount Wechecha. The general comparison of land cover class of the five periods is summarized in Table 3 below. Agricultural land cover after it reaches a peak in 2003, starts to fall in 2013. The main reason for the reduction of agricultural land is the abrupt increase of the settlement in the study area. The people who previously depended mainly economically on agriculture, recently started to shift to other economic sectors. For instance, house renting due to settlement expansion, small trades and also started to get involved in small service sectors.

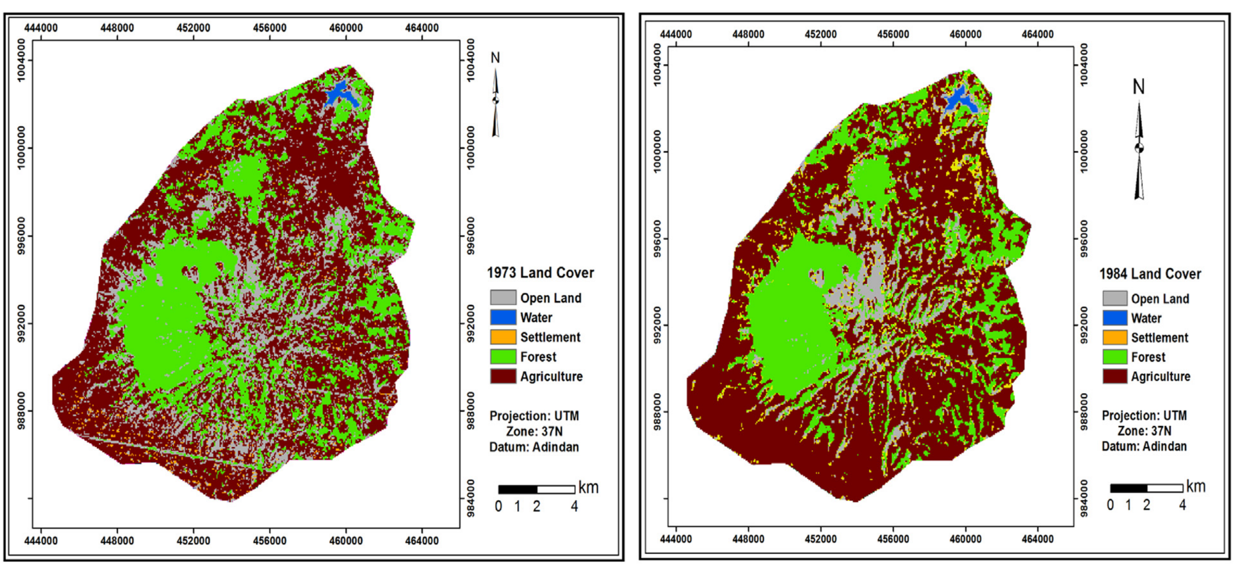

Fig. 6. Land cover class of 1973(left) and 1984(right).

3.2. Characteristics of the landscape structure in the study area

3.2.1. Metrics characteristics of the landscape of Mount Wechecha

3.2.1.1. 1973 landscape and class metrics analyses. The mean shape index of 1973 indicates that water has the highest MSI, about 2.4 followed by agricultural land 1.55. This shows that the patch shape in

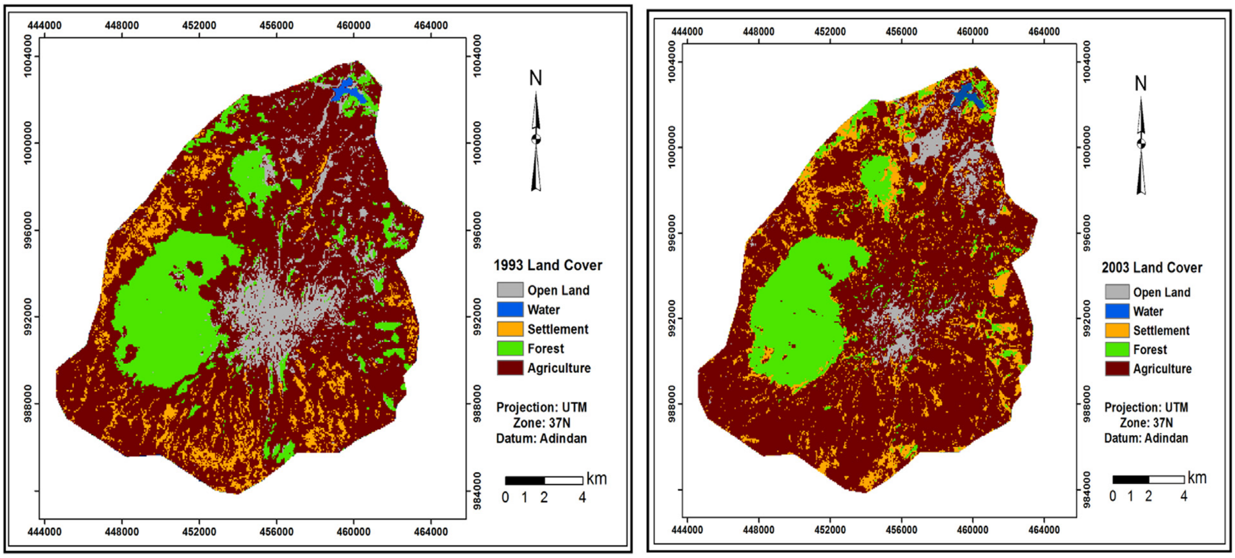

Fig. 7. Land cover class of 1993(left) and 2003(right).

this area is regular for settlement and most irregular for water body. If the proportion of perimeter to area is larger, the boundary value patch is larger, and the intensity of fringed effect is also larger and viceversa (Jia et al., 2008). This time, the total number of patches are 3612. The Core Area Density (CAD) value for water and settlement is zero while it is the highest for agriculture. The total landscape area explained is 24,977 ha while the highest class area is for agriculture, about 12,325 ha. Gefersa dam is the single water body considered as a patch this time. The edge density(amount of edge relative to the landscape area) is the highest for agriculture(77.7 m per hectare). Regarding the mean patch fractal dimension all the land cover classes have simple shape complexity. The highest MPFD is for water which is 1.13 and the least is for settlement (1.02).

3.2.1.2. 1984 landscape and class metrics analyses. In 1984 the number of patches decreased to 3027. The highest patch distribution is for open land and the least for water. The highest mean shape index during this time was, for water (2.45) and the least for settlement (1.18). Both values are increased compared to the 1973. Regarding the mean patch fractal dimension all the land cover classes have simple shape complexity. The highest MPFD is for water which is 1.13 and the least is for settlement (1.07). Only insignificant MPFD is observed compared to 1973. Note that the total number of patch mean does not

Table 3
Summarized land cover of the study area in different periods.

Year	Water (Hec)	Settlement (Hec)	Forest (Hec)	Open Land(Hec)	Agriculture (Hec)
1973	83.49	329.5	7559.5	6161.73	10,983.2
1984	89.28	496	5280	2892.25	16,369
1993	85.93	2053	4512	2270	16,137
2003	93.75	3058	3865	1036.75	16,969
2013	123	6580	3634	602.5	14,118.5

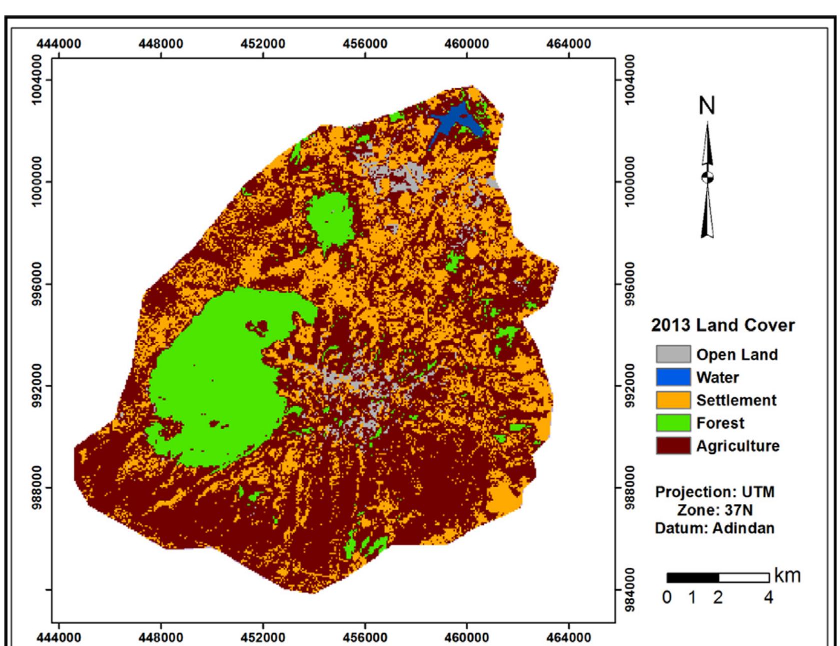

Fig. 8. Land cover class of 2013, derived from Landsat 8.

necessarily have a relationship with the total area. The Shannon diversity and evenness is 0 which shows the similar result for all five times classification on this study. The CAD value is the highest for the forest and the least for water body. The MCA (average core area per patch) is the highest for water body, and least for settlement. Agriculture shares the highest class area followed by forest this time.

3.2.1.3. 1993 landscape and class metrics analyses. In 1993 the total number of patch is 3499. The highest patch number is for open spaces and settlement respectively. Total edge for open land and settlement is also the highest during this time. Agriculture and forest's mean core area is increased this time compared to 1984. The mean shape index in 1993, the highest is for water (2.29) and the least for settlement and forest (1.4). Settlement and forest have equal MSI value this time. Both values are increased compared to the 1984. Regarding the mean patch fractal dimension all the land cover classes have simple shape complexity. The highest MPFD is for water which is 1.12 and all the rest have nearly similar low MSI. The Shannon diversity and evenness is 0. The CAD value is the highest for the settlement and agriculture. Water body has 0 CAD value during this time also. The class area of settlement increased to 2044.71. Total edge is the highest for agriculture and the least for water body patch. Edge density is the highest for agriculture and settlement. Water has the highest MCA about 69.7 and settlement patches have a lowest core area about 1.08.

3.2.1.4. 2003 landscape and class matrix analyses. In 2003, the total number of patch is decreased to 2124. The number of patch of water is split into two patches this time, and increased in class area to 93 ha. Open land class is abruptly decreased this time. The mean shape index is the highest is for water (1.65), even though it is decreased compared to the previous times. All the rest land cover classes have nearly similar MSI value. Forest and agriculture have similar 1.27 MSI while open land and settlement have equally 1.28. Regarding the mean patch fractal dimension all the land cover classes have simple shape complexity. The highest MPFD is for water which is 1.06 and all the rest have nearly similar lowest MSI (1.02–1.04). The CAD value is the highest for the settlement and agriculture patches. Water body patches has 0 CAD value. The class area of settlement is increased to 3047.89 ha

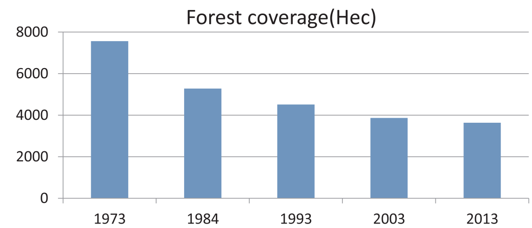

Fig. 9. Forest cover change trend on Mount Wechecha.

in 2003. Edge Density is the highest for agriculture and settlement, 53.2 and 41.8 respectively. Shannon's Evenness index and Diversity index is 0 for all patches. The mean core area of the forest is increased to 51.7, from 21.8 in 1993. The least mean core area is for settlement and open land respectively.

3.2.1.5. 2013 landscape and class metrics analyses. In 2013 the total number of patch is reduced to 1768, the highest number of patch is settlement with 987 and the least number of patches is for water. This time forest is limited only to 182 patches. The mean fractal dimension of all patches with 1.03 in average indicates that the shape complexity is simple. The water body is split into three patches this time and its area coverage is raised to 122 ha. Open land class is diminished to 605 ha. The mean shape index is the highest for water (1.53), even though it decreased compared to the previous time periods. All the rest of the land cover patches have nearly similar MSI value. Forest and agriculture have 1.24 and 1.33 MSI value respectively. Regarding the mean patch fractal dimension all the land cover classes have simple shape complexity. The highest MPFD is for water and settlement is 1.05. Other land cover classes have similar 1.03 MPFD value. The CAD value is the highest for the settlement and agriculture. Water body has 0 CAD value. Water body is the only land cover type which has 0 CAD value in all five periods' analyses. Forests MCA is increased to 84.9, because the forests are clearly confined to two protected area. The mean Core area of Agriculture falls to 11.4 in 2013 from 47.8 in 2003. This is because of landscape fragmentation; the continuous agricultural land is getting interrupted by settlement. The class area of settlement jumped to 6531 ha in 2013 from 3047.89 ha in 2003. The summary of selected landscape metrics from 1973 to 2013 is given in Table 4

Table 4
Selected class and landscape level spatial metrics of 2013.

Year	Class	MCA	TCA	TCAI	CAD	MSI	MPFD	AWM-PFD	TE	ED	MPS	NUMP	TLA	CA
1973	Forest	11.1	3986.2	53.0	1.4	1.4	1.1	1.2	110,443	44.2	10.9	687	24,977.3	7519.8
	Agriculture	5.0	4046.6	37.1	3.2	1.5	1.1	1.3	209,931	84.1	16.8	647	24,977.3	10,903.3
	Water	25.1	50.4	60.3	0.0	2.4	1.1	1.1	8778.	0.4	83.5	1	24,977.3	83.5
	Settlement	0.0	0.0	0.0	0.0	1.1	1.0	1.0	196,080	7.9	0.5	630	24,977.3	327.8
	Open Land	1.6	936.0	15.3	2.4	1.4	1.1	1.2	192,568	77.1	3.7	1647	24,977.3	6135.7
1984	Forest	16.8	4091.4	59.9	1.0	1.4	1.1	1.2	811,920	32.4	12.8	532	24,989.8	6827.2
	Agriculture	41.2	9658.0	67.7	0.9	1.3	1.0	1.3	114,780	45.9	75.5	189	24,989.8	14,273.9
	Water	50.0	50.0	59.4	0.0	2.5	1.1	1.1	9000	0.4	84.2	1	24,989.8	84.2
	Settlement	0.7	22.3	1.5	0.1	1.2	1.0	1.1	740,160	29.6	0.9	1654	24,989.8	14,273.3
	Open Land	2.9	501.1	21.9	0.7	1.3	1.0	1.2	610,440	24.4	3.5	651	24,989.8	2289.2
1993	Forest	21.8	3771.4	83.7	0.7	1.4	1.1	1.2	400,380	16.0	13.1	344	24,975.7	4504.7
	Agriculture	26.0	12,379.9	77.0	1.9	1.3	1.0	1.4	188,088	75.3	24.6	651	24,975.7	16,069.3
	Water	67.9	67.9	79.4	0.0	2.3	1.1	1.1	8460	0.3	85.5	1	24,975.7	85.6
	Settlement	1.1	650.6	31.8	2.4	1.4	1.1	1.2	874,920	35.0	1.9	1102	24,975.7	2044.7
	Open Land	2.7	1028.6	45.4	1.5	1.3	1.0	1.3	784,140	31.4	1.6	1401	24,975.7	2267.8
2003	Forest	51.7	3001.0	77.7	0.2	1.3	1.0	1.1	282,834	11.3	14.1	273	24,977.3	3858.8
	Agriculture	48.7	11,816.6	69.7	1.0	1.3	1.0	1.3	133,003	53.2	83.4	203	24,977.3	16,944.2
	Water	59.7	59.8	63.9	0.0	1.7	1.1	1.1	9120	0.4	46.7	2	24,977.3	93.6
	Settlement	1.9	459.7	15.1	1.0	1.3	1.0	1.2	104,595	41.8	2.2	1385	24,977.3	3047.9
	Open Land	4.9	325.8	31.6	0.3	1.3	1.0	1.2	253,650	10.1	4.0	261	24,977.3	1030.6
2013	Forest	84.9	2972.8	81.8	0.1	1.2	1.0	1.1	204,480	8.2	19.9	182	24,989.7	3633.1
	Agriculture	11.4	7084.8	50.3	2.5	1.3	1.0	1.4	194,652	77.8	35.5	396	24,989.7	14,076.4
	Water	75.2	75.2	61.7	0.0	1.5	1.1	1.1	11,880	0.5	40.6	3	24,989.7	122.0
	Settlement	2.9	1596.6	24.5	2.2	1.4	1.1	1.3	162,936	65.2	6.6	987	24,989.7	6531.1
	Open Land	1.9	88.6	14.6	0.2	1.2	1.0	1.1	202,200	8.1	2.0	300	24,989.7	605.5

Note that: the SDI and SEI values for all period is 0.

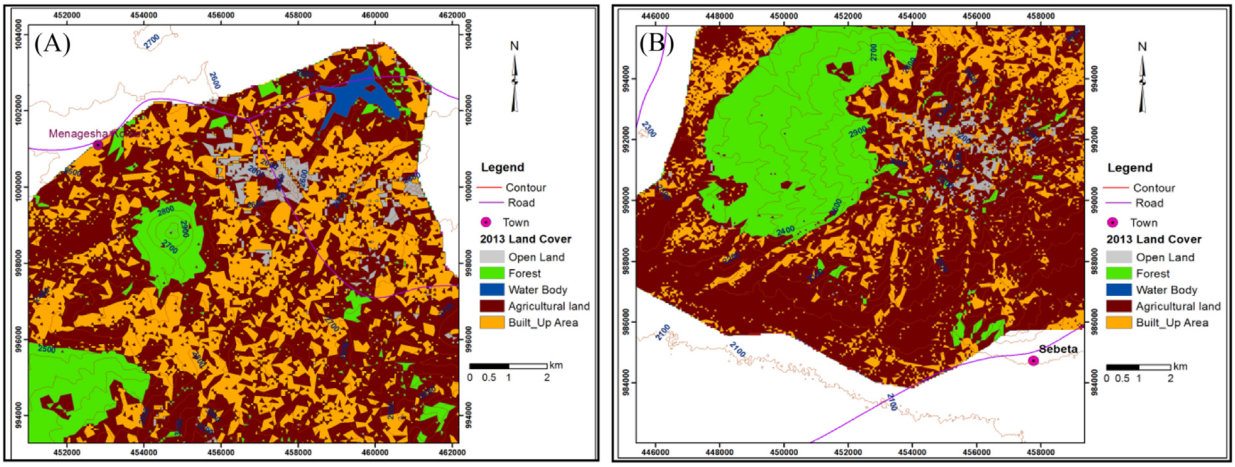

Fig. 10. Landscape Structure of Northern (A) and Southern (B) part of Mount Wechecha.

3.2.2. *Forest change*

Of the five land cover types identified in the previous section, emphasis is given to forest cover change in the study area because forests is one of the most important valuable natural resource and play a key role in ecological balance. It is previously raised that the forest cover in the mountain is decreasing from time to time (Fig.9). The decrease of forest matrices in CA, CAD, MSI, MPFD, ED and NUMP between 1973 and 2013 indicated that the forest of the area is in danger. However since 1993 to present, only insignificant reduction is occurred, this is because the sites are protected and some new plants are also planted. Currently, cutting trees and disturbing the forest is not allowed and the safety of the forest is protected by the government.

3.2.3. *Vectorised landscape map of the study area*

Until now the metrics described are derived from the images prepared in raster grid format. However the latest and recent 2013 patch classes are converted to vector format to prepare a final landscape structure map. To display the map properly and landscape characteristics, the study area is divided into two parts (North and south) in large scale compared to the previous maps. Since the size, shape and pattern of the patches will not be easily identified if prepared in a scale similar with the previous maps. The contour lines derived from 30 m SRTM data in 100 m contour interval is added to the vectorised map. The contour lines help to show the elevation characteristics of the landscape. Additional man made features like road and towns are included on the map. The characteristics of the previous metrics indicated in number are now indicated and viewed on the map. The patches of settlement patterns are dissected and fragmented than any other type of landscape patterns. They have irregular shapes. Forest patches are more confined to specific area and have regular shape than others. From time to time, the forest patches found between two protected forest patches are eliminated (Fig. 10).

In the southern and south western parts of the mountain, the largest protected forest, called Menagesha Suba is found. Except the protected forest, other places are devoid of trees. Open places are also confined to the top of the mountain

High population pressure and agriculture makes the mountain peaks appear devoid of natural vegetation. The highly elevated places of the mountain are also inhabited by the settlement and agriculture. The Wechecha Mountain peak has unique landscapes that could be preserved and could have a higher ecotourism potential if protected properly. However, the settlement and agriculture become the main characteristics of the study area. Many traditional houses constructed from wood and mud (tukuls), are built till the top of the mountain, and hundreds of people are settled on the mount Wechecha.

4. Discussion

4.1. *Implication of the results*

The result has shown that the vegetation cover of the Mount Wechecha decreased from time to time, whereas the settlement is currently increasing at an alarming rate. In recent years the agricultural lands are also getting converted into settlements. As a result the previous landscape is modified overtime. The number of patches of other land cover types, except for settlement and water body is decreasing. The open land is diminished, and replaced by settlement and agriculture. The landscape structure indices, like number of patches, are decreasing from time to time except for water and settlement. The forest patches are dissolved to agricultural lands. The mean core area of the forest that increases indicates that the forest coverage is limited to certain places. The MCA of an agricultural land has decreased for this decade since the agricultural land is also interrupted by other economic activity or landscape modification highly by settlement. It should be noted that, this study finding is in line with many land cover change studies undertaken in mountainous areas mainly in Ethiopia. For instance Tolessa et al. (2016), undertook study on Landscape composition and configuration in the On Jibat Forest, found west of Mount Wechecha, which indicated that cultivated land and settlement land increased at the expense of forestland, shrub land, and grassland as well as the level of fragmentation and interspersion is high. Deforestation, land fragmentation and habitat loss are common in many parts of Ethiopia, not only in the protected places, but also, in the protected and identified natural forests including parks (Fetene et al., 2014) Mountains, in their nature demand an individual approach, essentially because the effects of slope and elevation – or 'verticality' – add a unique dimension to the challenges present in the lowlands. In all mountain regions, natural risks are high and the effects of poor land use practice are particularly severe (United Nations Environment Programme and World Conservation Monitoring Centre, 2002). The deforestation activity of mount Wechecha does not affect only the localities within the mountain but also has a great influence on the neighbouring places.

Despite Mount Wechecha being partly the source of water for Gefersa Reservoir, and plays a key role in regulating the climate of the surrounding area, and the highest elevated place found near capital Addis Ababa, most parts of the mountain are devoid of trees except protected sites of Menagesha-Suba and Egdu state forests. However, the elders who have lived in the area for a long period of time witnessed that most parts of the mountain used to be covered by natural forests. The results obtained from the satellite image analysis also confirms that the previously forest covered areas have deteriorated alarmingly from time to time. Once the natural forests are cleared from most parts of the mountain, people start to plant eucalyptus trees used in their day to day

Fig. 11. Livelihood of the area is based on the forest wood.

activities. Now it is common to see the eucalyptus tree in all villages and settlements, even up to the top of the mountain. It has been widely recalled that Eucalyptus species have been introduced since 1895 to satisfy the growing demand for wood and construction material and to reduce the pressure on the remaining natural vegetation during the reign of emperor Menilik II (Hancock, 1995).

Mount Wechecha should be preserved because of its ecological importance. Unless the upper parts of the mountain are protected, managed well, and reforested, the eroded materials from the mountain could make the depth of the dam shallow and increase evaporation. Flooding is also among the problems related to the mountain because of poor land use and slope of the mountain. The land cover and land use practices that have environmental impact like extensive horticulture farms in the area and settlement across the hilltop should be controlled. At the foot of the mountain settlements are grown to towns. Flower farms, industries, high and rapid settlement patterns are established following the main roads. These make environmental quality of the area poor.

One of the main ecological importances of forests found on Mount Wechecha is climate regulation for Addis Ababa, and the surrounding towns. The capital city is bordered by mountain chains from all directions. The land transformation on these mountains has its influence on the climate of the city. Currently it is reported that signals of climate change like flooding, urbanization induced heat wave, increasing temperature and rise of temperature have started to appear in Addis Ababa (Birhanu et al., 2016; Abebe and Megento, 2016; Climate Change and Urban Vulnerability in Africa (CLUVA), 2011; Conway et al., 2004). and protecting the nearby mountains like mount Wechecha helps to know the mechanism of intervention and strategy to be followed to control environmental issues, mainly climate regulation in Addis Ababa and the surrounding towns.

4.2. Reasons for deforestation

Ethiopia's forest resource conservation, development and utilization today is not the product of a long evolving process in which different land-use planning measures have been devised and used to meet changing needs and various ecological conditions of the country. The absence of sound and comprehensive land-use policies encompassing the identification, selection and appropriation of suitable areas for forestry development based on production and environmental protection is the outstanding forestry problems in Ethiopia (MOA, 1991). Though there were different attempts made to prepare land use plans at macro and micro river basin levels in the last six decades, the implementation faced lack of enforcement and regulatory mechanisms. The road map identifies bottlenecks, which hindered the implementation and successfulness of the past land use planning initiatives, as insufficient awareness and sensitization among decision makers, lack of involvement of the major stakeholders (beneficiaries), absence of coordination between different government agencies, lack of legal framework and limited implementation capacity (Gebeyehu et al., 2017).

The forest management intervention was available since the beginning of 20th century formal forest policy started in 20th century, and mainly during the brief period of Italian annexation (Melaku, 2003). Forestry was, most of the times, marginalized or integrated into the dominant agricultural development paradigm, where the integration also failed to maximize the synergy between the two sectors (Ayana et al., 2013).

Recently, even though, there is no severe lack of policies and strategies or laws and regulations, people are forced to implement it due to economic problems. The implementation fails, mainly due to low level of economic development in the community. Even people cut trees despite their awareness even if they know the laws, and the ecological benefits of the trees. On Mount Wechecha, people have based their livelihoods on agriculture, animal herding, and use of forest resources (timber, fuel wood, fodder). The main economic activity that takes place on the mountain is agriculture. However in addition to agriculture, specifically in previous times, the mountain trees were cleared for economic purposes. The local people used to cut the trees and bring them to the town. However since the forests are cleared and others are protected, recently, people started to plant eucalyptus tree and sell the products to earn money.

Fig. 11 indicates the eucalyptus products taken to the market for sale by local people.

5. Conclusion and recommendations

Using satellite image as the main source data for the landscape structure mapping and change study, this paper analyses and investigates the landscape pattern and forest cover change in line with other land cover types on the Mount Wechecha, which is the highest elevated point above 3000 m found in south western part of Addis Ababa. The study takes 10 year intervals Landsat satellite images starting from the 1970's, and identifies changes in main landscape pattern for the past 40 years. The land cover classification divides the land cover types into five coarse groups. These are settlement, forest, open land, water body and agricultural land. The result of classification indicates that land cover types like settlement is increasing abruptly while forest and open lands are decreasing. Specifically in between 1973 and 1984, high rate of open land deterioration occurred. In between 1984 and 1993, high rate of forest is decreased. The natural forest is currently covering 3634 ha and only found in the two protected sites, ménagesha Suba and Egdu forest. Other places are used for agriculture and settlement activities. The Geferesa Reservior is the only water body identifiable from the satellite image from the study area. The reservoir shows an increment of 123 ha in to 2013 from 83 ha in 1973.

Regarding the results obtained from metrics, the number of patches of the study area decreased from time to time for patches classes like forest and open lands, while the number of patches for settlement increases from time to time. The indices result obtained from patch analyst is proportional to the land cover classes obtained from the image. The landscape structure indices for instance, number of patches

are decreasing from time to time except for water and settlement. The forest patches are dissolved to agricultural lands. The mean core area of the forest that increases indicates that the forest coverage is limited to certain places. The MCA of an agricultural land decreased for this decade as the agricultural land is also interrupted by other economic activity or landscape modification. Other indices like the Shannon's evenness and diversity index is zero.

Due to high deforestation and poor environment management the previous forest cover area cleared and used for other activities. Preserving and protecting the natural landscape of the degraded parts of mount Wechecha, should be given a due consideration because, the mountain is, part of Gefersa River Water shade and a source for small streams, a high elevated mountain with many ecological benefits like climate regulation, due to its fauna and floristic composition from the foot of the mountain to the top of the mountain, it provides a spectacular scenery and spiritual places are also found on the mountain. Therefore conservation planning like agro-forestry and preservation should be maintained.

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